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Dated 28 OCT 1998

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The Patent Office

Request for grant of a Patent

Form 1/77

Patents Act 1977

❶ Title of invention

1 Please give the title of the invention: A METHOD FOR PREDICTING INTERFERENCE

❷ Applicant's details

First or only applicant

2a If you are applying as a corporate body please give:

Corporate name: MOTOROLA LTD

Country (and State of incorporation, if appropriate): United Kingdom

2b If you are applying as an individual or one of a partnership please give in full:

Surname

Forenames

2c In all cases, please give the following details:

Address:
Jays Close
Viables Industrial Estate
Basingstoke
Hampshire RG22 4PD
England

UK postcode (if applicable)

Country: United Kingdom

ADP number (if known)

2d, 2e and 2f: If there are further [app]licants please provide details on a separate sheet of paper.

☐ Second applicant *(if any)*

2d If you are applying as a corporate body please give:

Corporate name

Country *(and State of incorporation, if appropriate)*

2e If you are applying as an individual or one of a partnership please give in full:

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❸ An address for service in the [U]nited Kingdom must be supplied

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❸ Address for service details

3a **Have you appointed an agent to deal with your application?**

Yes ☒ No ☐ → *go to 3b*

please give details below

Agent's name

Agent's address

SARAH GIBSON

MOTOROLA, EUROPEAN
INTELLECTUAL
PROPERTY OPERATIONS
MIDPOINT, ALENCON LINK
BASINGSTOKE, HAMPSHIRE

Postcode RG21 7PL

Agent's ADP number 7272239001

[I]f you have appointed an agent, all correspondence concerning your [appl]ication will be sent to the agent's United Kingdom address.

3b If you have not appointed an agent please give a name and address in the United Kingdom to which all correspondence will be sent:

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Daytime telephone number *(if available)*

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4 Reference number

4 Agent's or applicant's reference number *(if applicable)*

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5 Claiming an earlier application date

5 Are you claiming that this application be treated as having been filed on the date of filing of an earlier application?

Please mark correct box

Yes ☐ No ☒ → *go to 6*

↓

please give details below

☐ number of earlier application or patent number

☐ filing date

(day month year)

☐ and the Section of the Patents Act 1977 under which you are claiming:

Please mark correct box

15(4) (Divisional) ☐ 8(3) ☐ 12(6) ☐ 37(4) ☐

6 Declaration of priority

...ou are declaring priority from a ...plication please enter 'PCT' as ... country and enter the country (for example, GB) as part of the application number.

...ase give the date in all number ...mat, for example, 31/05/90 for 31 May 1990.

6 If you are declaring priority from previous application(s), please give:

Country of filing	Priority application number *(if known)*	Filing date *(day, month, year)*

The answer must be 'No' if:
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· is an inventor who is not an applicant, or
· applicant corporate body.

7 Inventorship

7 Are you (the applicant or applicants) the sole inventor or the joint inventors?

Please mark correct box

Yes ☐ No ☒ → *A Statement of Inventorship on Patents Form 7/77 will need to be filed (see Rule 15).*

Please supply duplicates of claim(s), abstract, description and drawing(s).

8 Checklist

8a Please fill in the number of sheets for each of the following types of document contained in this application.

Continuation sheets for this Patents Form 1/77	–
Claim(s)	3
Description	9
Abstract	1
Drawing(s)	4

8b Which of the following documents also accompanies the application?

Please mark correct box(es)

Priority documents *(please state how many)*	–
Translation(s) of Priority documents *(please state how many)*	–
Patents Form 7/77 – Statement of Inventorship and Right to Grant *(please state how many)*	2
Patents Form 9/77 – Preliminary Examination/Search	X
Patents Form 10/77 – Request for Substantive Examination	–

...r your appointed agent (see ...1 of the Patents Rules 1990) must sign this request.

9 Request

I/We request the grant of a patent on the basis of this application.

Please sign here →

Signed Sarah Gibson

SARAH GIBSON Date 15/12/97

(day month year)

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A METHOD FOR PREDICTING INTERFERENCE

Field of the Invention

The present invention relates to a method for predicting interference in a communications network, for example, a cellular telecommunications network, such as a Global System for Mobile Communications (GSM) network.

Background of the Invention

When a cellular telephone network is planned, it is known in the art to employ a three cell reuse pattern. Such a pattern comprises a plurality of sites, each of the plurality of sites being divided into three cells and allocated a predetermined number of frequencies for the purpose of frequency hopping. A first cell is allocated a first set of frequencies, a second cell is allocated a second set of frequencies and a third cell is allocated a third set of frequencies. The frequencies and the allocation thereof is identical for each site.

However, such a plan does not account for sources of interference, for example, geographic obstacles and topography of the terrain covered by the network. This often leads to some cells having lower capacity than the majority of cells. The lower capacity cells set a limit on the network capacity as a whole.

It is therefore an object of the present invention to obviate or mitigate the problems associates with frequency planning in a cellular network.

Summary of the Invention

According to a first aspect of the present invention, there is provided, a method for predicting interference experienced by a first cell from a second cell, both cells having at least one frequency hopping parameter, the method comprising the steps of: determining an estimated interference level corresponding to interference experienced by the first cell due to the second

cell; calculating the probability of the first cell hopping to substantially the same frequency as the second cell; weighting the estimated interference level with the calculated probability, and modifying the at least one frequency hopping parameter in order to modify the weighted estimated interference level.

According to a second aspect of the present invention, there is provided a method of optimising calculations corresponding to a first cell in a frequency hopping network, comprising the steps of: fitting a probability model to the probability of cells in the network hopping to substantially the same frequency; determining the cells in the network which have a probability above to a predetermined threshold of hopping to substantially the said frequency, and executing the calculations for the first cell based upon the sources of interference to the first cell which are in the determined cells.

Other, preferred, features and advantages will become apparent from the accompanying dependent claims and the following description.

It is thus possible to provide a method and apparatus for optimising a communications network which has the maximum capacity achievable by controlling the level and probability of interference associated with frequency hopping.

Brief Description of the Drawings

At least one embodiment of the invention will now be described, by way of example, with reference to the accompanying drawings, in which:

FIG. 1 is a schematic diagram of three cells in a cellular network for use with the present invention;

FIG. 2 is a block diagram of frequencies assigned to the three cells of FIG. 1;

FIG. 3 is a flow diagram constituting an embodiment of the present invention;

FIG. 4 is a flow diagram of a step shown in FIG. 3;

FIG. 5 is a flow diagram of an enhancement of FIG. 3, and

FIG. 6 is a probability distribution for use with the enhancement of FIG. 5.

Description of a Preferred Embodiment

A cellular telecommunication network 100 (FIG.1), for example, a GSM network, comprises a first cell 102, a second cell 104 and a third cell 106 having a respective first base station 108, second base station 110 and third base station 112 located therein. The first, second and third cells 102, 104, 106 are, for simplicity of description, omicells, but other cell configurations known in the art can be used. The first, second and third base stations 106, 108, 110 can be M-CELL base stations manufactured by Motorola Limited.

Referring to FIG. 2, a first set of frequencies 200 is allocated to the first cell 102. The first base station 108 operates in a frequency hoping mode and can select any frequency from the first set of frequencies 200 for transmission of a time slot.

A second set of frequencies 202 is allocated to the second cell 104. The second base station 110 operates in a frequency hoping mode and can select any frequency from the second set of frequencies 202 for transmission of a time slot.

Similarly, a third set of frequencies 204 is allocated to the third cell 106. The third base station 112 operates in a frequency hopping mode and can select any frequency from the third set of frequencies 204 for transmission of a time slot.

Operation of the invention will now be described with reference to FIG. 3.

A cell is selected for optimisation (step 300), for example, the first cell 102, by setting a variable, test_cell, equal to 1. The system determines (step 302)

whether a total number of the cells for optimisation, c, have had their corresponding interference level calculated. In the above simplified example, c is equal to 3.

An interference level and associated statistical data for the first cell, I_{cell1}, is calculated (step 304) as follows.

Referring to FIG. 4, an interference matrix $I_{(c,c)}$ is generated (step 402) containing interference levels corresponding to the predicted interference experienced by each cell in the network as a result of other cells in the network. The interference levels can be measured, or estimated using the Netplan software package supplied by Motorola, Inc. The interference matrix $I_{(c,c)}$ has a structure as shown in Table 1 below.

	Cell 1	Cell 2	...	...	...	Cell c
Cell 1	$I_{(1,1)}$	$I_{(1,2)}$	...	...	...	$I_{(1,c)}$
Cell 2	$I_{(2,1)}$	$I_{(2,2)}$	...	...	...	$I_{(2,c)}$
...	...	...	...	...	...	...
...	...	...	...	...	...	...
Cell c	$I_{(c,1)}$	$I_{(c,2)}$	...	...	...	$I_{(c,c)}$

Table 1

When the Netplan software is used, a range of interference levels are generated corresponding to the interference levels at different locations in, for example, the first cell 102. In order to calculate a corresponding single value for each element of the interference matrix $I_{(c,c)}$, it is necessary to process the range of interference levels generated relating to, for example, the first cell 102 in order to obtain the single value corresponding to a nominal interference level. Such processing techniques can include the statistical mode, medium or mean, or the maximum or minimum interference level in, for example, the first cell 102. This processing technique is repeated with appropriate changes so as to calculate each entry in the interference matrix $I_{(c,c)}$. It should be appreciated that other processing techniques known in the art can be used to obtain each single value.

Once the element of the interference matrix $I_{(c,c)}$ has been calculated (step 402), a combination table containing data relating to the possible different combinations of cells interfering with the first cell 102 is generated (step 404) as shown in Table 2 below.

Cell 2	Cell 3
0	0
0	1
1	0
1	1

Table 2

The above table conforms to an incremental binary sequence. Table 2 forms part of a larger table (Table 3) shown below (the last four rows of the columns relating to Cell 2 and Cell 3). However, when optimising the first cell 102, those cells which can interfere with the first cell 102 are only of interest and so the first four rows of the table are ignored.

Cell 1	Cell 2	Cell 3
0	0	0
0	0	1
0	1	0
0	1	1
1	0	0
1	0	1
1	1	0
1	1	1

Table 3

The 1's in the combination table (Table 2) represent the possibility of a cell interfering with the first cell 102. The 0's in the matrix represent the possibility of a cell not interfering with the first cell 102.

Given the frequency allocation of FIG. 2, it is possible to calculate a first probability of the first cell 102 hopping to a substantially identical frequency as the second cell 104.

The first probability can be expressed as:

$P\{h_2\}$ = P{Both cell 1 and cell 2 hop to the same frequency} = P{cells 1 and 2 hop to f_1} OR P{cells 1 and 2 hop to f_2} OR P{cell 1 and 2 hop to f_3}

$$=\frac{1}{4}.\frac{1}{3}+\frac{1}{4}.\frac{1}{3}+\frac{1}{4}.\frac{1}{3}=\frac{1}{4}$$

Similarly, it is also possible to calculate a second probability of the first cell 102 hopping to a substantially identical frequency as the third cell 106.

The second probability can be expressed as:

$P\{h_3\}$ = P{Both cell 1 and cell 3 hop to the same frequency} = P{cells 1 and 3 hop to f_2} OR P{cells 1 and 3 hop to f_3} OR P{cell 1 and 3 hop to f_4}

$$=\frac{1}{4}.\frac{1}{3}+\frac{1}{4}.\frac{1}{3}+\frac{1}{4}.\frac{1}{3}=\frac{1}{4}$$

It should be appreciated that the values of the first and second probabilities will depend upon the number of frequencies in common between the first, second and third sets 200, 202, 204 of frequencies and the number of frequencies used for hopping. The first and second probabilities can be calculated according to any method known in the art.

Each row of the combination table (Table 2) is then analysed to identify cells which could possibly interfere with the first cell 102 and an expected interference value is calculated (step 406) for each row as follows.

An entry in the combination table (Table 2) indicating a possible interference with the first cell 102, i.e. having a '1' in the appropriate location, is identified. Thus, no 1's are present in the first row and so this row contemplates the situation where neither cell 2 nor cell 3 interfere with cell 1. Consequently, an expected interference level of 0 is recorded.

The second row signifies the possible interference between the first cell 102 and the third cell 106 only. The interference level $I_{(1,3)}$ in the interference matrix $I_{(c,c)}$ corresponding to the interference experienced by the first cell 102 due to the third cell 106 is extracted from the interference matrix $I_{c,c}$. If another entry were to exist in the second row of the combination table (Table 2), an additional entry in the interference matrix $I_{(c,c)}$ is identified and extracted.

Once all of the possible interfering cells have been identified for the second row in the combination table (Table 2), the interference levels extracted are multiplied, or weighted, by corresponding probabilities calculated above relating to the probability of two cells hopping to a substantially identical frequency. For example, for the second row of the combination table (Table 2), the calculation will be as follows:

$$p(h_3) \times I_{(1,3)}$$

The same procedure is applied to the third and fourth rows of the combination table (Table 2). Thus, for the third row, the weighted interference level is calculated as follows:

$$p(h_2) \times I_{(1,2)}, \text{ and}$$

for the fourth row, the weighted interface level is calculated as follows:

$$p(h_2) \times I_{(1,2)} + p(h_3) \times I_{(1,3)}$$

The weighted interference levels corresponding to each row of the combination table (Table 2) are then summed in order to generate an interference level corresponding to the possible combination of cells which can interfere with Cell 1.

The next cell to be optimised is then selected by incrementing (step 306) the variable, test_cell. It is then determined whether all the cells have been analysed (step 302), i.e. whether c has been reached.

The above process is then repeated for each cell to be optimised until weighted interference levels have been generated for each of the cells to be optimised.

A probability density function (PDF) corresponding to the weighted interference levels of the cells to be optimised is generated (step 408), for example, using a "bin count" method known in the field of statistics, and a cumulative density function (CDF) is then generated (step 410) using the PDF.

An analytical or visual means for representing the weighted interference levels of the cells is thereby provided.

The poorest performing cells are then identified using either the weighted interference levels or the CDF, and can be optimised by modifying the number and distribution of frequencies (step 314) in order to modify the weighted interference levels so as to obtain an optimum interference level throughout the network.

It should be appreciated that the interference levels are not the only criteria which can be used to optimise the network and other criteria, for example, probability levels can be used.

The above example has been described with reference to three cells for simplicity and clarity. However, it should be appreciated that a greater number of cells can be employed in the network 100.

As a further enhancement (FIG. 5) to the above technique, the interference characteristics of the network 100 can be modelled using a probability distribution, for example, a binomial distribution (step 600).

The binomial distribution can then be used to reduce the number of computations required by determining the number of cells which are likely to contribute significantly to interference experienced by a given cell.

For example, as shown in FIG. 6, the network 100 may comprise 19 cells using 6 identical frequencies for frequency hopping. The binomial distribution for such an arrangement shows that the probability of 10 cells or more using the same frequency at the same time is very low. Therefore, in order to reduce the computational burden, the first 10 strongest interfering cells (which can be determined from the interference matrix $I_{(c,c)}$) can be used (step 602) for network optimisation in accordance with the method described above, instead of using all the cells in the network. An additional modification to the method being that the interference matrix is generated (step 604 and step 606) based upon the selected number of interfering cells.

Since a subset of all possible permutations of cells is only considered, a correction factor can be applied, for example, a simple ratio between the number of permutations ignored and the number of total possible permutations. However, if the contribution to the interference level from the ignored cells is minimal, the correction factor may not be required.

Claims

1. A method for predicting interference experienced by a first cell from a second cell, both cells having at least one frequency hopping parameter, the method comprising the steps of:

determining an estimated interference level corresponding to interference experienced by the first cell due to the second cell;

calculating the probability of the first cell hopping to substantially the same frequency as the second cell;

weighting the estimated interference level with the calculated probability, and

modifying the at least one frequency hopping parameter in order to modify the weighted estimated interference level.

2. A method as claimed in Claim 1, wherein the at least one frequency hopping parameter is the number of frequencies used by the first cell.

3. A method as claimed in Claim 1 or Claim 2, wherein the at least one frequency hopping parameter is the number of frequencies used by the second cell.

4. A method as claimed in any one of the preceding claims, wherein the at least one frequency hopping parameter is the choice of frequencies used for frequency hopping by the first cell.

5. A method as claimed in any one of the preceding claims, wherein the at least one frequency hopping parameter is the choice of frequencies used for frequency hopping by the second cell.

6. A method as claimed in any one of the preceding claims, further comprising providing further cells having further corresponding frequency hopping parameters, and

determining further estimated interference levels corresponding to interference experienced by the first cell due to further cells;

calculating the further probabilities of the first cell hopping to substantially the same frequency as each of the further cells;

weighting the further estimated interference levels with the corresponding calculated further probabilities, and

modifying the at least one frequency hopping parameter in order to optimise the weighted estimated interference level and the further weighted estimated interference levels.

7. A method as claimed in any one of the preceding claims, further comprising forming a matrix including the estimated interference level and the further estimated interference levels.

8. A method as claimed in any one of the preceding claims, further comprising forming a probability density function based on the weighted estimated interference level and the further weighted estimated interference levels.

9. A method as claimed in Claim 9, further comprising forming a cumulative density function based on the probability density function.

10. A method of optimising calculations corresponding to a first cell in a frequency hopping network, comprising the steps of:

fitting a probability model to the probability of cells in the network hopping to substantially the same frequency;

determining the cells in the network which have a probability above to a predetermined threshold of hopping to substantially the said frequency,

executing the calculations for the first cell based upon the sources of interference to the first cell which are in the determined cells.

11. A method as claimed in Claim 10, wherein the calculations are as claimed in any one Claim 1 to 9.

12. A method as claimed in Claim 10 or Claim 11, wherein the determined cells comprise the strongest sources of interference in the network.

13. A method as claimed in any one of Claims 10 to 12, wherein the probability model is a binomial probability model.

14. A method for predicting interference experienced by a first cell from a second cell substantially as hereinbefore described with reference to the accompanying drawings.

A METHOD FOR PREDICTING INTERFERENCE

Abstract of the Invention

A method for predicting interference experienced by a first cell (102) from a second cell (104), where both cells (102, 104) have at least one frequency hopping parameter, comprises the steps of determining (step 402) an estimated interference level corresponding to interference experienced by the first cell (102) due to the second cell (104); calculating the probability of the first cell hopping to substantially the same frequency as the second cell; weighting (step 406) the estimated interference level with the calculated probability, and modifying (step 314) the at least one frequency hopping parameter in order modify the weighted estimated interference level.

(FIG. 3)

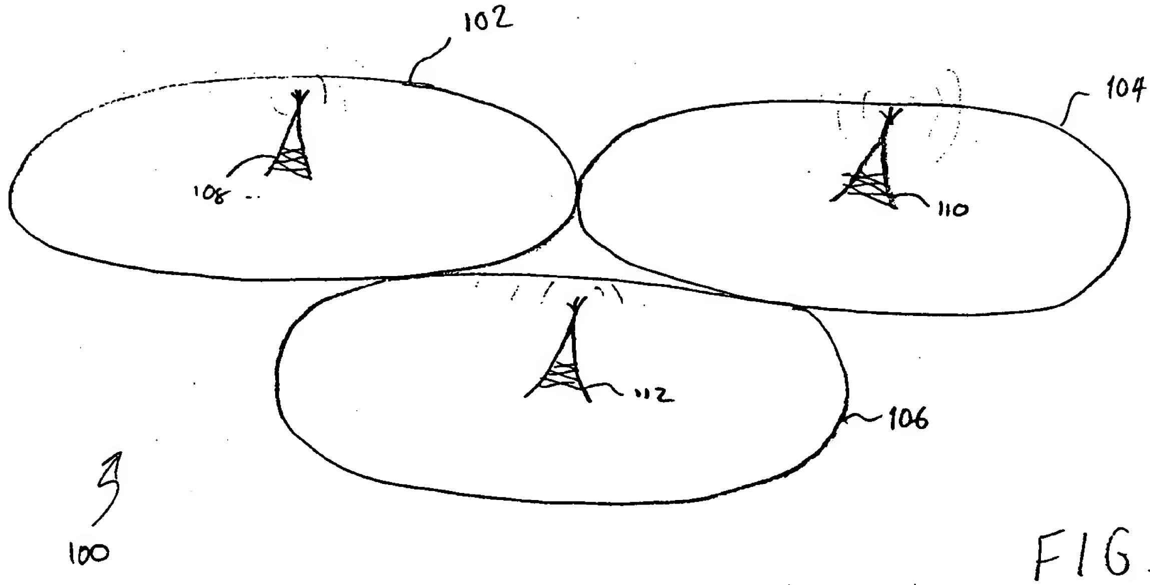

FIG. 1

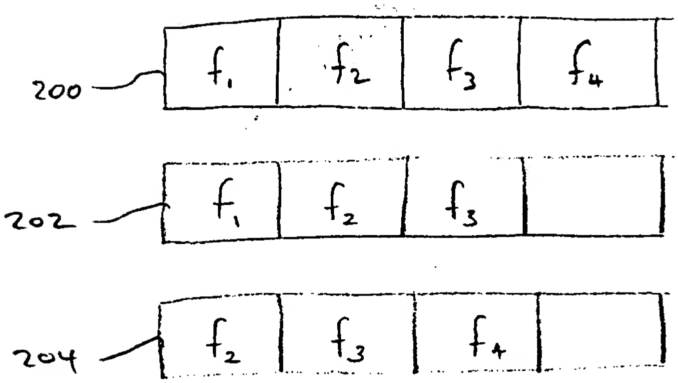

FIG. 2

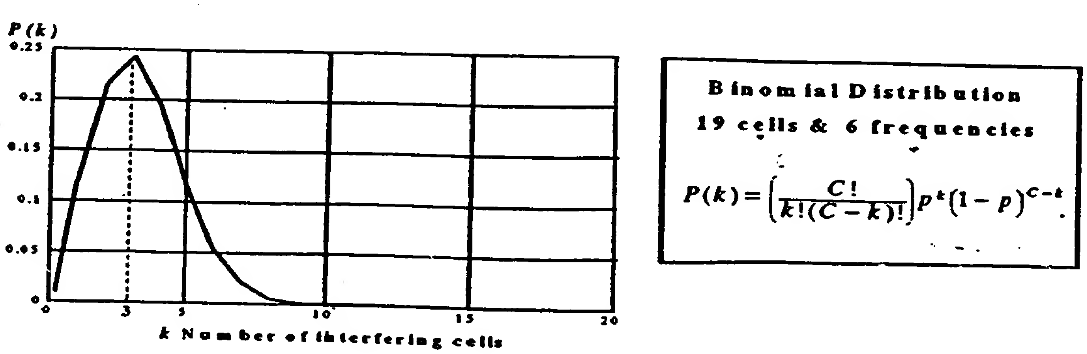

FIG. 6

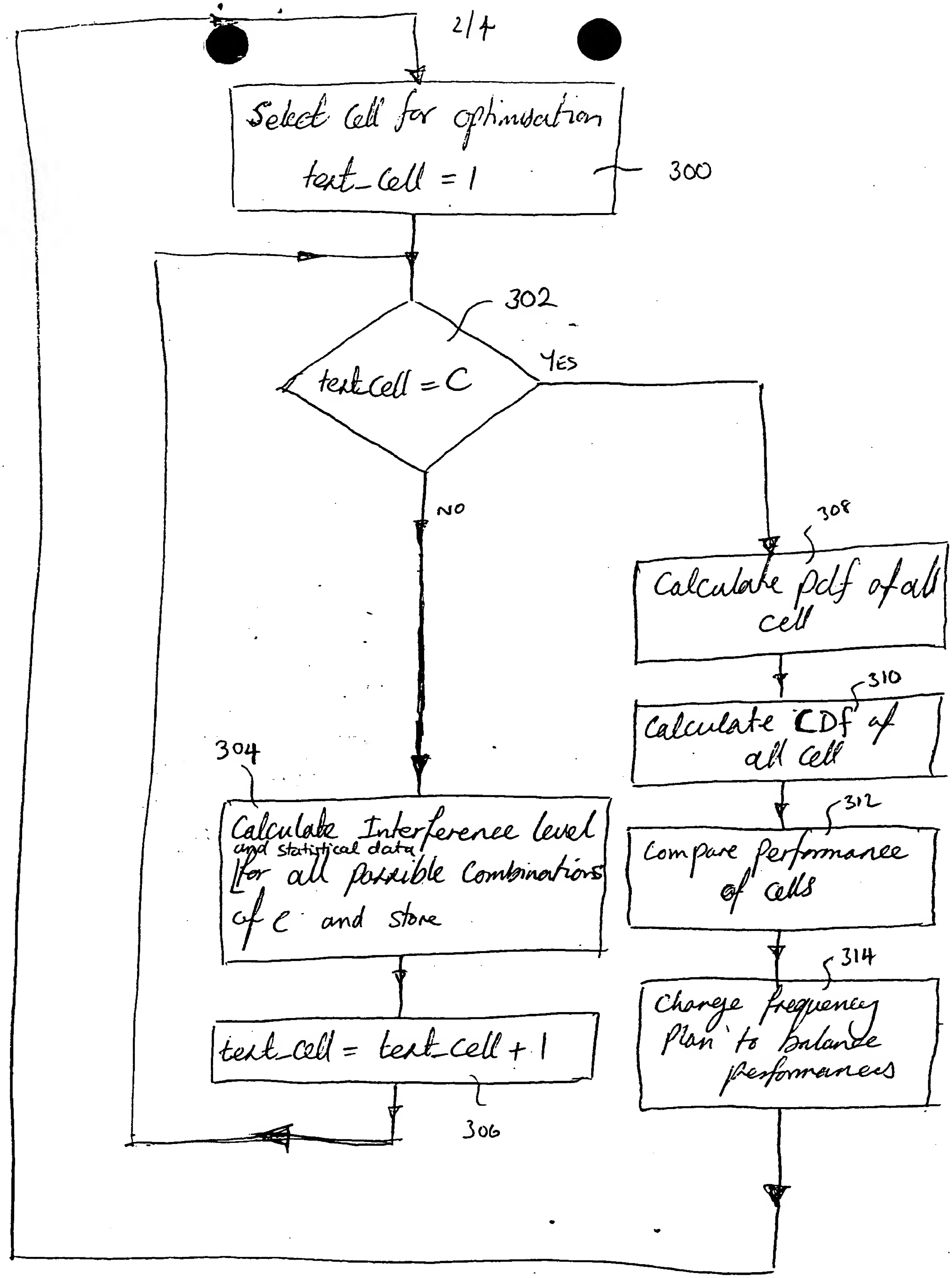
Select cell for optimisation
text_cell = 1
300
302
text_cell = C
YES
NO
308
Calculate pdf of all cell
310
Calculate CDF of all cell
312
Compare performance of cells
314
Change frequency plan to balance performances
304
Calculate Interference level and statistical data for all possible combinations of C and store
text_cell = text_cell + 1
306

FIG. 3

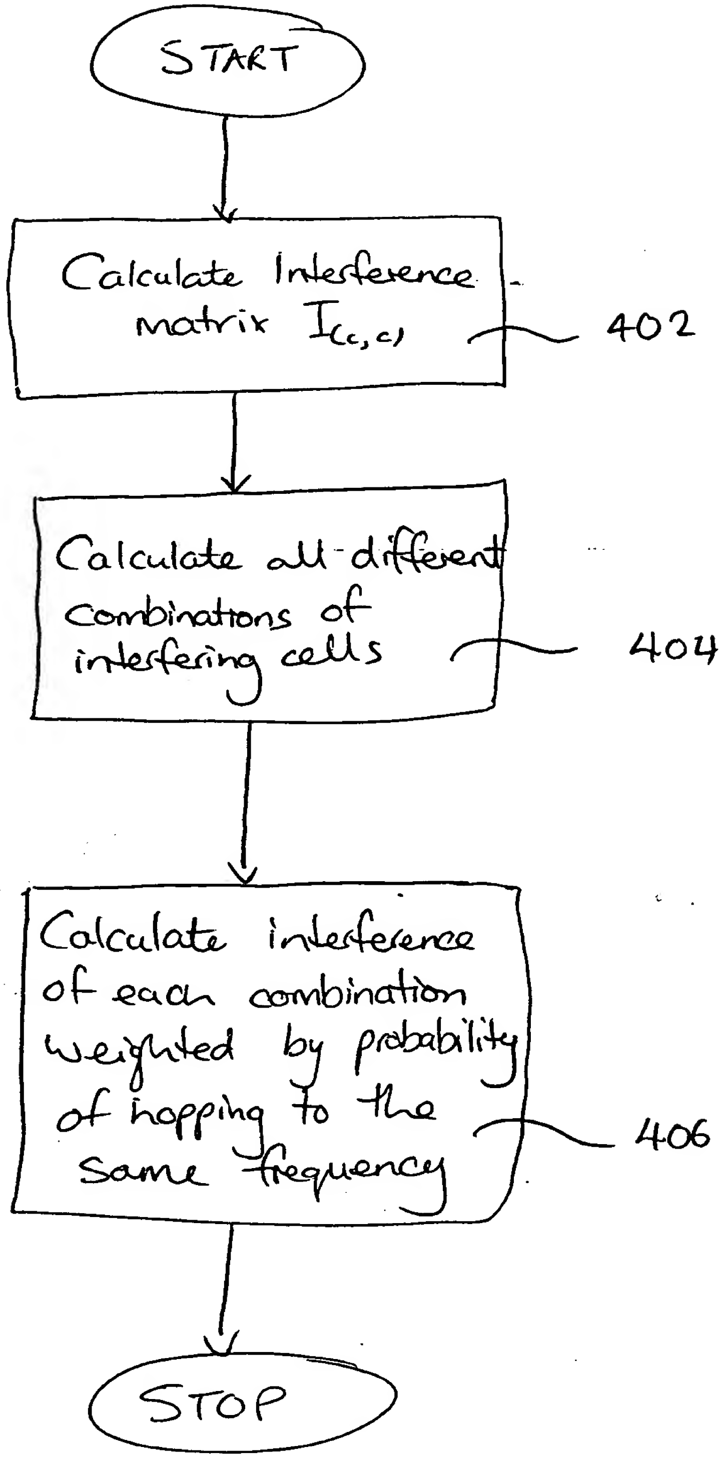
START
Calculate Interference matrix $I_{(c,c)}$
402
Calculate all different combinations of interfering cells
404
Calculate interference of each combination weighted by probability of hopping to the same frequency
406
STOP

FIG. 4

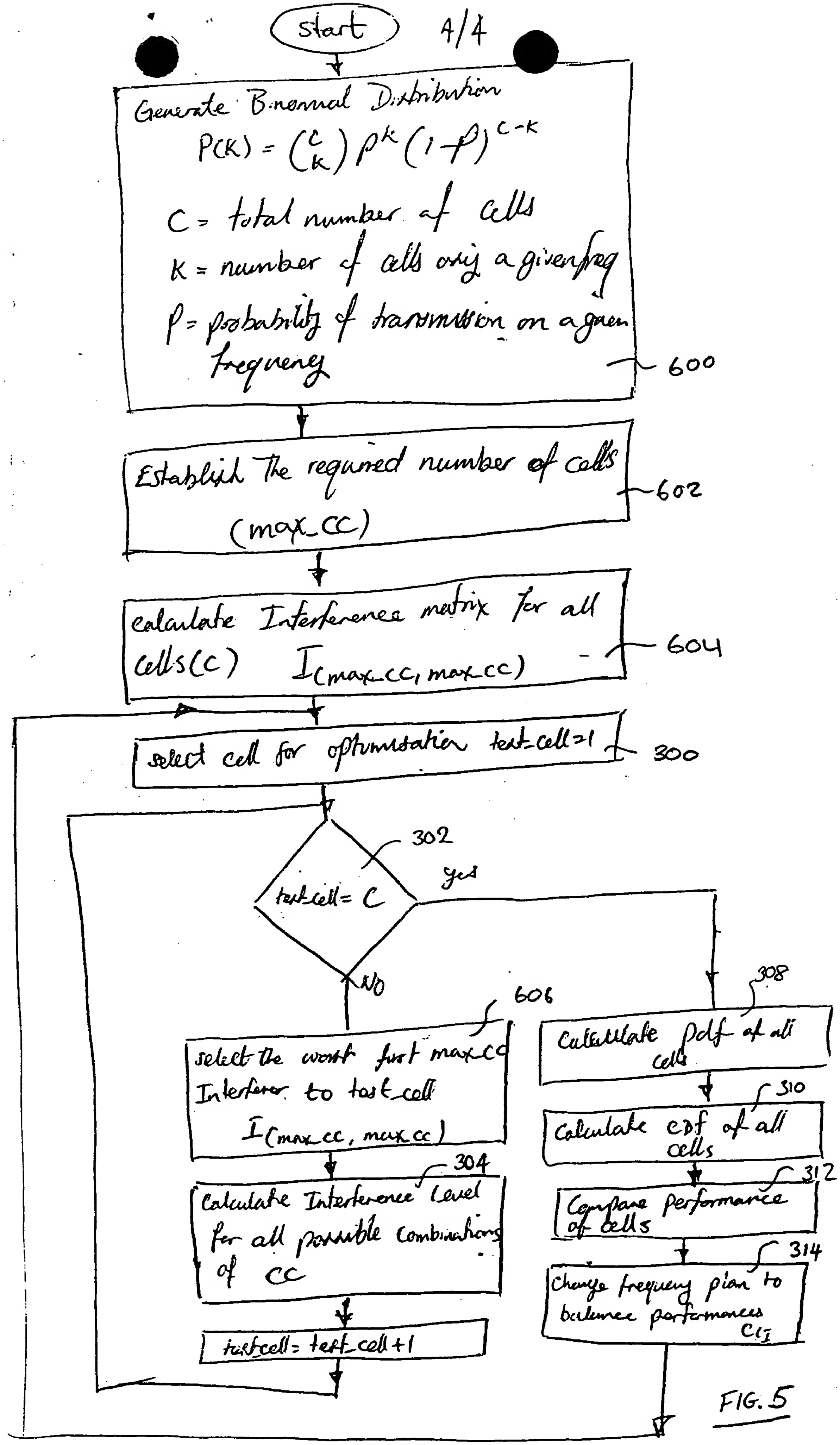
Start
Generate Binomal Distribution
$P(K) = \binom{C}{K} \rho^{K} (1-\rho)^{C-K}$
C = total number of cells
K = number of cells using a given freq
ρ = probability of transmission on a given frequency
600
Establish the required number of cells (max_cc)
602
calculate Interference matrix for all cells (C) $I_{(max\_cc,\, max\_cc)}$
604
select cell for optimisation test_cell = 1
300
test_cell = C
302
yes
No
select the worst first max_cc Interferer to test_cell $I_{(max\_cc,\, max\_cc)}$
606
Calculate Interference Level for all possible combinations of CC
304
test_cell = test_cell + 1
Calculate pdf of all cells
308
Calculate cdf of all cells
310
Compare performance of cells
312
Change frequency plan to balance performances CI
314

FIG. 5